CLAIMS:

What is claimed is:

1. A method for simulating a magnetoresistive memory device of a magnetoresistive random access memory (MRAM) having a first conductor, a second conductor, and a magnetic tunnel junction (MTJ), the first conductor disposed substantially orthogonal to the second conductor, the MTJ disposed between the first conductor and the second conductor, the method comprising:

calculating a first current in the first conductor;

calculating a second current in the second conductor;

detecting an indication of a transition of one of the first current and the second current across a threshold;

modifying a status of an operating condition of a plurality of operating conditions in response to the detecting the indication of the transition; and

outputting a bit state that is dependent upon a status of the plurality of operating conditions.

2. The method of claim 1 further comprising:

calculating a current conducted through the MTJ based on a logic value of the bit state.

3. The method of claim 2 further comprising:

modeling a conductance value of the MTJ in each of two bit states using an equation having an equivalent form of $G(A+BV+CV^2)$, where G is a conductance value of the MTJ, A, B, and C are zero, first, and second order voltage coefficient parameters, and V is a MTJ bias voltage value.

4. The method of claim 3 further comprising:

utilizing a first set of zero, first, and second order voltage coefficient parameters for the conductance value for a first bit state and utilizing a second set of, zero, first, and second order voltage coefficient parameters for the conductance value for a second bit state.

5. The method of claim 3 further comprising:

in at least one of the two bit states, utilizing a first set of zero, first, and second order voltage coefficient parameters for the conductance value for a positive MTJ bias voltage and utilizing a second set of zero, first, and second order voltage coefficient parameters for the conductance value for a negative MTJ bias voltage.

6. The method of claim 3 further comprising:

calculating A, B, and C as a function of temperature.

7. The method of claim 3 wherein values of G, A, B, and C are generated by a method comprising:

fitting low resistance state conductance data, high resistance state conductance negative bias voltage data, and high resistance state conductance positive bias voltage data for predetermined temperatures with second order polynomials; and

fitting individual polynomial coefficient parameters to first order temperature polynomials.

8. The method of claim 7 further comprising using one of a root mean square error or a weighted root mean square error in performing the fitting.

9. The method of claim 7 wherein the values of G, A, B, and C are generated by a method further comprising:

adjusting one or more of the individual polynomial coefficient parameters to minimize a total error being measured between the second order polynomials and each of the low resistance state conductance data, the high resistance state conductance negative bias voltage data, and the high resistance state conductance positive bias voltage data.

10. The method of claim 9 wherein the values of G, A, B, and C are generated by a method further comprising:

using one of a root mean square error or a weighted root mean square error.

11. The method of claim 9 wherein the values of G, A, B, and C are generated by a method further comprising:

eliminating one or more of the polynomial coefficient parameters which have a minimal effect on error being measured.

12. The method of claim 1 wherein the detecting an indication of a transition of one of the first current and the second current across a threshold, further includes:

calculating a first magnetic field from the first current;

calculating a second magnetic field from the second current;

detecting a transition of one of the first magnetic field and the second magnetic field across a threshold.

13. The method of claim 1 wherein:

the plurality of operating conditions include a condition indicative of a presence of a current in the first conductor above a predetermined threshold, a condition indicative of a presence of a current in the second conductor above a predetermined threshold, a condition indicative of a presence of a current in the first conductor above a predetermined threshold preceding a presence of a current in the second conductor above a predetermined threshold, and a condition indicative of a presence of a current in the second conductor above a predetermined threshold preceding a presence of the current in the first conductor above a predetermined threshold.

14. The method of claim 1 wherein the threshold is one of:

a first threshold corresponding to the first current exceeding a lower threshold while increasing;

a second threshold corresponding to the first current exceeding a higher threshold while increasing;

a third threshold corresponding to the second current exceeding a lower threshold while increasing; and

a fourth threshold corresponding to the second current exceeding a upper threshold while increasing.

15. The method of claim 1 wherein the calculating the first current and the calculating the second current are performed during each time step of a simulation of an MRAM memory.

16. A method of simulating a memory device of a magnetoresistive random access memory (MRAM), the memory device having a magnetic tunnel junction (MTJ) with multiple free magnetic layers, the method comprising:

calculating an indication of a first magnetic field applied to the MTJ;

calculating an indication of a second magnetic field applied to the MTJ;

detecting an indication of a transition of one of the first magnetic field and the second magnetic field across a threshold;

modifying a status of an operating condition of a plurality of operating conditions in response to the detecting the indication of a transition; and

providing an output bit state for the memory device, the output bit state is dependent upon a status of the plurality of operating conditions.

17. The method of claim 16 wherein:

the plurality of operating conditions include a condition indicative of a presence of the first magnetic field above a predetermined threshold, a condition indicative of a presence of the second magnetic field above a predetermined threshold, a condition indicative of a presence of the first magnetic field above a predetermined threshold preceding a presence of the second magnetic field above a predetermined threshold, and a condition indicative of a presence of the second magnetic field above a predetermined threshold preceding a presence of the first magnetic field above a predetermined threshold.

18. The method of claim 16 further comprising:

calculating a current conducted through the magnetic tunnel junction (MTJ) of the memory device based on a logic value of the bit state.

19. The method of claim 18 further comprising:

modeling a conductance value of the MTJ in each of two bit states using an equation having an equivalent form of $G(A+BV+CV^2)$, where G is a conductance value of the MTJ, A, B, and C are zero, first, and second order voltage coefficient parameters, and V is a MTJ bias voltage value.

20. The method of claim 19 further comprising:

utilizing a first set of zero, first, and second order voltage coefficient parameters for the conductance value for a first bit state and utilizing a second set of zero, first and second order voltage coefficient parameters for the conductance value for a second bit state.

21. The method of claim 19 further comprising:

in at least one of the two bit states, utilizing a first set of zero, first, and second order voltage coefficient parameters for the conductance value for a positive MTJ bias voltage and utilizing a second set of zero, first, and second order voltage coefficient parameters for the conductance value for a negative MTJ bias voltage.

22. The method of claim 19 further comprising:

calculating A, B, and C as a function of temperature.

23. The method of claim 19 wherein values of G, A, B, and C are generated by a method comprising:

fitting low resistance state conductance data, high resistance state conductance negative bias voltage data, and high resistance state conductance positive bias voltage data for predetermined temperatures with second order polynomials; and

fitting individual polynomial coefficient parameters to first order temperature polynomials.

24. The method of claim 23 wherein the values of G, A, B, and C are generated by a method further comprising:

adjusting one or more of the individual polynomial coefficient parameters to minimize a total error being measured between the second order polynomials and each of the low resistance state conductance data, the high resistance state conductance negative bias voltage data, and the high resistance state conductance positive bias voltage data.

25. The method of claim 24 wherein the values of G, A, B, and C are generated by a method further comprising:

eliminating one or more of the polynomial coefficient parameters which have a minimal effect on error being measured.

26. The method of claim 16 wherein:

the calculating an indication of a first magnetic field applied to the MTJ further includes calculating a first current in a first write conductor;

the calculating an indication of a second magnetic field applied to the MTJ further includes calculating a second current in a second write conductor;

the first write conductor is disposed substantially orthogonal to the second write conductor with the MTJ disposed between the first write conductor and the second write conductor.

27. The method of claim 26 wherein:

the calculating an indication of a first magnetic field applied to the MTJ further includes calculating the first magnetic field from the first current;

the calculating an indication of a second magnetic field applied to the MTJ further includes calculating the second magnetic field from the second current.

28. The method of claim 16 wherein the threshold is one of:

a first threshold corresponding to the first magnetic field exceeding a lower threshold while increasing;

a second threshold corresponding to the first magnetic field exceeding a higher threshold while increasing;

a third threshold corresponding to the second magnetic field exceeding a lower threshold while increasing; and

a fourth threshold corresponding to the second magnetic field exceeding a upper threshold while increasing.

29. A method for simulating a magnetoresistive memory device in an integrated circuit magnetoresistive random access memory (MRAM) having a first conductor, a second conductor, and a magnetic tunnel junction (MTJ), the first conductor disposed substantially orthogonal to the second conductor, the MTJ disposed between the first conductor and the second conductor, the method comprising:

calculating an indication of a first magnetic field applied to the MTJ, the first magnetic field generated by current in the first conductor;

calculating an indication of a second magnetic field applied to the MTJ, the second magnetic field generated by current in the second conductor;

detecting indications of transitions of the first magnetic field and the second magnetic field across one or more thresholds; and

providing a state machine having one or more state variables with transitions in the state machine being dependent upon detected indications of transitions of the first magnetic field and the second magnetic field and a state of the one or more state variables.

30. The method of claim 29 further comprising:

modeling a conductance value of the MTJ in each of two bit states by using an equation having an equivalent form of $G(A+BV+CV^2)$, where G is a conductance value of the MTJ, A, B, and C are zero, first, and second order voltage coefficient parameters, and V is a MTJ bias voltage value.

31. The method of claim 30 further comprising:

utilizing a first set of zero, first, and second order voltage coefficient parameters for the conductance value for a first bit state and utilizing a second set of zero, first, and second order voltage coefficient parameters for the conductance value for a second bit state.

32. The method of claim 30 further comprising

in at least one of the two bit states, utilizing a first set of zero, first, and second order voltage coefficient parameters for the conductance value for a positive MTJ bias voltage and utilizing a second set of zero, first, and second order voltage coefficient parameters for the conductance value for a negative MTJ bias voltage.

33. The method of claim 30 further comprising:

calculating A, B, and C as a function of temperature.

34. The method of claim 30 wherein values of G, A, B, and C are generated by a method comprising:

fitting low resistance state conductance data, high resistance state conductance negative bias voltage data, and high resistance state conductance positive bias voltage data for predetermined temperatures with second order polynomials; and

fitting individual polynomial coefficient parameters to first order temperature polynomials.

35. The method of claim 34 wherein the values of G, A, B, and C are generated by a method further comprising:

adjusting one or more of the individual polynomial coefficient parameters to minimize a total error being measured between the second order polynomials and each of the low resistance state conductance data, the high resistance state conductance negative bias voltage data, and the high resistance state conductance positive bias voltage data.

36. The method of claim 35 wherein the values of G, A, B, and C are generated by a method further comprising:

eliminating one or more of the polynomial coefficient parameters which have a minimal effect on error being measured.

37. The method of claim 29 wherein state variables of the state machine include:
a state variable indicative of a presence of the first magnetic field above a predetermined threshold;
a state variable indicative of a presence of the second magnetic field above a predetermined threshold;
a state variable indicative of a presence of the first magnetic field above a predetermined threshold preceding a presence of the second magnetic field above a predetermined threshold; and
a state variable indicative of a presence of the second magnetic field above a predetermined threshold preceding a presence of the first magnetic field above a predetermined threshold.

38. The method of claim 29 wherein the MTJ includes multiple free magnetic layers.

39. The method of claim 29 wherein the one or more thresholds include:
a first threshold corresponding to the first magnetic field exceeding a lower threshold while increasing;
a second threshold corresponding to the first magnetic field exceeding a higher threshold while increasing;
a third threshold corresponding to the second magnetic field exceeding a lower threshold while increasing;
a fourth threshold corresponding to the second magnetic field exceeding a upper threshold while increasing.

40. The method of claim 29 wherein:
the calculating an indication of a first magnetic field applied to the MTJ further includes calculating a first current in the first conductor;
the calculating an indication of a second magnetic field applied to the MTJ further includes calculating a second current in the second conductor.

41. A computer readable medium having stored instructions for simulating a magnetoresistive memory device of a magnetoresistive random access memory (MRAM) including a first conductor, a second conductor, and a magnetic tunnel junction (MTJ), the first conductor disposed substantially orthogonal to the second conductor, the MTJ disposed between the first conductor and the second conductor, the MTJ having multiple free magnetic layers, the computer readable medium comprising:

instructions for calculating an indication of a first magnetic field applied to the MTJ, the first magnetic field being generated by current in the first conductor;

instructions for calculating an indication of a second magnetic field applied to the MTJ, the second magnetic field being generated by current in the second conductor;

instructions for detecting indications of transitions of the first magnetic field and the second magnetic field across one or more thresholds;

instructions for modifying a status of operating conditions in response to detecting the indications of transitions of one of the first magnetic field and the second magnetic field across one or more thresholds; and

instructions for outputting a bit state that is dependent upon the status of the operating conditions.